STUDIES ON PERFORMANCE AND WEAR CHARACTERISTICS OF CENTRIFUGAL SLURRY PUMPS HANDLING MULTI-SIZED CONCENTRATED PARTICULATE SLURRIES

by

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CERTIFICATE

This is to certify that the thesis entitled **STUDIES ON PERFORMANCE AND WEAR CHARACTERISTICS OF CENTRIFUGAL SLURRY PUMPS HANDLING MULTI-SIZED CONCENTRATED PARTICULATE SLURRIES** being submitted by **B. K. Gandhi** to the **Indian Institute of Technology, Delhi (India)** for the award of the **Degree of Doctor of Philosophy in Applied Mechanics** is a record of bonafide research work carried out by him under our supervision and guidance. The thesis in our opinion, has reached the requisite standard fulfilling the requirement of Doctor of Philosophy Degree. The research report and the results presented in this thesis have not been submitted in parts or in full to any other University or Institute for the award of any degree or diploma.

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ABSTRACT

Centrifugal pumps are used extensively for hydraulic transportation of solids over short to medium distances through pipelines where the requirements of head and discharge are moderate. A centrifugal pump designed to handle solid-liquid mixtures is normally single stage, end suction type having radial and mixed flow configuration to facilitate the motion of solid particles. Some of the special features of the centrifugal slurry pumps are larger flow passages to accommodate solid particles, robust impeller with lesser number of vanes, special seals and proper material of construction to ensure longer life. These have to be operated with relatively wide clearances at impeller-casing contacts to minimise choking and localised wear. These modifications increase the hydraulic losses in the pump and deteriorate the pump performance. During the design of pumps handling abrasive slurries, the requirement of longer life and reliability have to be balanced by the constraint of high initial cost and efficiency.

Review of literature suggests the need for additional investigations on centrifugal slurry pumps to generate experimental data to achieve optimum design. Studies on pump characteristics with concentrated multi-sized particulate slurries are few and there exists a need for comprehensive study on pumps handling commercial slurries to gain further insight. The present study is aimed at generating extensive data and provide some insight into the existing gaps in the knowledge related to the effect of solids on the performance and wear characteristics of centrifugal slurry pumps.

To achieve the above objectives, experimental investigations have been carried out on two centrifugal slurry pumps. The performance of a 50 mm pump has been

evaluated experimentally at rated speeds (1450 rpm) with water and solid-liquid mixtures at different solid concentrations with three solid materials namely bed ash, fly ash and zinc tailings. All the solid materials used are multi-sized with wide variation in particle size distribution and size. The performance of the pump with fly ash and zinc tailing slurries has also been evaluated at two more speeds namely 1150 rpm and 1750 rpm. At all the speeds, the head developed and the efficiency of the pump is found to reduce with increase in solid concentration and the effect is strongly dependent on particle size distribution and slurry properties. The power input to the pump is also found to increase linearly with specific gravity of the slurry at low solid concentrations (<30% by weight) where as at higher concentrations, the rate of increase in the input power is comparatively lower and does not follow linear variation. Similar studies on head-capacity characteristics for 100 mm pump with fly ash and zinc tailings slurries at rated speed(1250 rpm) also show agreement with these findings. However, the head losses for 100 mm pump are found to be comparatively lower than that for 50 mm pump, which demonstrates the dependence of performance on the pump size.

The performance of 50 mm pump obtained at three speeds has been further analysed to investigate the effect of speed on the pump performance with water and slurries. The non-dimensional head-capacity and power-capacity characteristics have been compared for water and slurries for different solid concentrations. It is found that the relationships for non-dimensional head and capacity according to affinity laws are also applicable for centrifugal slurry pump handling water but are not strictly valid for slurries. However, the relationship for the pump input power for speed variation is found invalid even with water.

In the second phase of the study, wear studies have been done in the volute casing and pot tester. A pot tester of 3.8 litre capacity available was suitably modified and special test fixtures were designed and fabricated out of a hard material to fix the brass wear pieces at the centre. Two such fixtures were fabricated and placed at 180^0 apart in the pot tester. The inner plane surface of the fixture could be fixed at any angle with respect to the plane of rotation ranging from 0^0 to 90^0 in steps of 15^0. The measurement of erosion wear for parallel flow to the surface of the specimen in the pot tester has been analysed to establish the effect of solid concentration, particle size and flow velocity on wear due to parallel flow. The effect of velocity on the parallel flow wear has been found to be much stronger compared to either solid concentration or particle size. A correlation has also been derived to establish the parametric dependence of the parallel flow wear. The total erosion wear measured at different impact angles has shown that the erosion wear first increases with increase in impact angle attaining a maximum value near 45^0 and then starts decreasing with increase in angle. The maximum shear angle for a ductile material is also around 45^0 indicating dominance of shearing action of the solid particles. The microscopic observations of the wear surfaces show different patterns of the eroded surface at different impact angles. Also, addition of finer particles (< 75 μ) in the equi-sized slurry has shown a significant reduction in the erosion wear. The measurements reveal that a replacement of 10% of the particles by finer particles in equi-sized coarse slurries reduces the wear by as much as 30 %.

To correlate the data generated on erosion in the pot tester, eleven wear pieces were fitted all along the wetted surface of the volute casing of 50 mm pump. The wear around the casing is measured for two solid concentrations and two flow rates. The variation of wear along the volute casing has been analysed. The study has allowed identification of the variation of impact angle of solid particles along the volute casing and demonstrated the applicability of the pot tester data to analyse the relative wear in the casing.

Another phase of the present study is the development of a methodology for the prediction of head-capacity characteristics of the centrifugal slurry pumps based on the estimation of various hydraulic losses. Basic details of the geometry of the pump have been used as input for estimation of various head/energy losses namely impeller slip loss, mixing loss, friction loss and leakage loss. The slip losses and leakage losses are significantly higher in the slurry pumps as compared to the conventional pumps. A computer programme has been developed to predict the head-capacity characteristics of both the pumps, used in the present experimental work. Satisfactory agreement has been found between the predicted and measured values in the normal operating range of the pumps.

On the basis of the present studies on centrifugal slurry pumps, the following conclusions have been drawn :

(1) The effect of pump size, solid concentration, specific gravity and particle size on the pump performance has been established. Head ratio has been found to depend largely on the amount of finer particles in the mixture and the particle size distribution.

(2) Wear data for nearly zero degree impact angle has been generated in a pot tester to establish the functional dependence of parallel flow wear on solid concentration, particle size and flow velocity. The work has been extended to include the effect of impact angle. It is observed that maximum wear in the case of ductile materials occurs at 45^0 impact angle. Addition of small amount of fine particles has shown a significant reduction in the wear. Wear in the pump casing can be correlated with the pot tester data.

(3) Non-dimensional relationships for head and capacity for centrifugal pumps are also found applicable for centrifugal slurry pumps handling clear water where as these relationships need to be modified for slurries. Similar relationship for power are not applicable even for water.

(4) An analytical procedure has been developed to predict the performance characteristics of centrifugal slurry pumps by estimating different energy /head losses taking place in the pump. The developed computer programme predicts the head-capacity characteristics of the pump reasonably well based on the knowledge of pump geometry and operating speed.

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